Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

Marine fishes and invertebrates are conspicuous members of continental shelf habitats, and assessment of their communities has become an important focus of ocean monitoring programs throughout the world. Assemblages of bottom dwelling (demersal) fishes and relatively large (megabenthic), mobile invertebrates that live on the surface of the seafloor have been sampled extensively for more than 30 years on the mainland shelf of the Southern California Bight (SCB), primarily by programs associated with municipal wastewater and power plant discharges (Cross and Allen 1993). More than 100 species of demersal fishes inhabit the SCB, while the megabenthic invertebrate fauna consists of more than 200 species (Allen 1982, Allen et al. 1998, 2002, 2007). For the region surrounding the Point Loma Ocean Outfall (PLOO), the most common trawl-caught fishes include Pacific sanddab, longfin sanddab, Dover sole, hornyhead turbot, California tonguefish, plainfin midshipman, and yellowchin sculpin. Common trawl-caught invertebrates include various echinoderms (e.g., sea stars, sea urchins, sea cucumbers, and sand dollars), crustaceans (e.g., crabs and shrimp), molluscs (e.g., marine snails and octopuses), and other taxa.

Demersal fish and megabenthic invertebrate communities are inherently variable and may be influenced by both anthropogenic and natural factors. These organisms live in close proximity to the seafloor and are therefore exposed to contaminants of anthropogenic origin that may accumulate in the sediments via deposition from both point and non-point sources (e.g., discharges from ocean outfalls and storm drains, surface runoff from watersheds, outflows from rivers and bays, disposal of dredge materials). Natural factors that may affect these organisms include prey availability (Cross et al. 1985), bottom relief and sediment structure (Helvey and Smith 1985), and changes in water temperatures associated with large scale oceanographic events such as El Niño/La Niña oscillations (Karinen et al. 1985). These factors can affect migration patterns of adult fish or the recruitment of juveniles into an area (Murawski 1993). Population fluctuations that affect species diversity and abundance of both fishes and invertebrates may also be due to the mobile nature of many species (e.g., fish schools, urchin aggregations).

The City of San Diego has been conducting trawl surveys in the area surrounding the present discharge site for the PLOO since 1991. These surveys are designed to monitor the effects of wastewater discharge on the local marine biota by assessing the structure and stability of the trawl-caught fish and invertebrate communities. This chapter presents analyses and interpretations of the data collected during the 2009 trawl surveys. A long-term analysis of changes in these communities from 1991 through 2009 is also presented.

Materials and Methods

Field Sampling

Trawl surveys were conducted at six fixed monitoring sites in the Point Loma region during 2009 (Figure 6.1). The six trawl stations, designated SD7, SD8, SD10, SD12, SD13 and SD14, are located along the 100-m depth contour, and encompass an area ranging from about 8 km north to 9 km south of the PLOO. A total of eight trawls were taken during two surveys in 2009. Sampling in January (winter) was limited to the two stations located nearest the outfall due to a resource exchange agreement to allow participation in the Bight'08 regional monitoring program (see Chapter 1), whereas all six stations were sampled during the July (summer) survey. A single trawl was performed at each station during each survey using a 7.6-m Marinovich otter

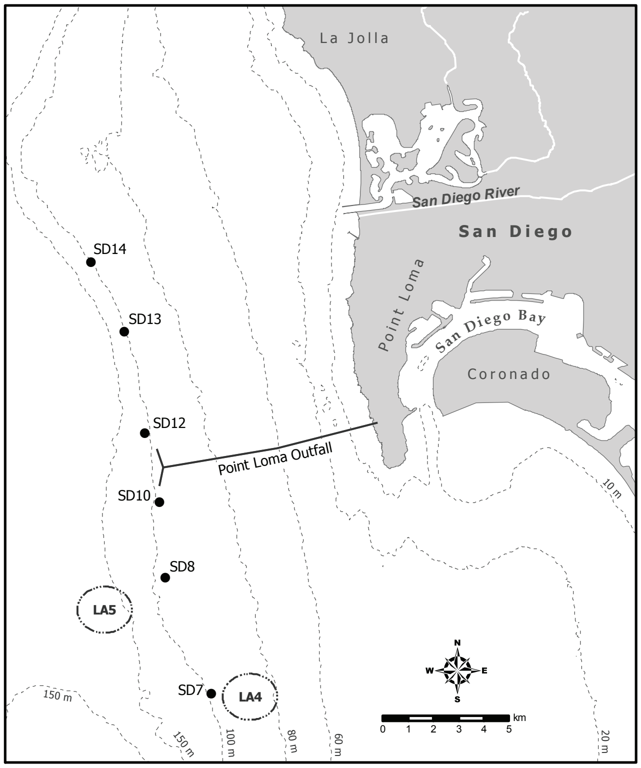

Figure 6.1
Otter trawl station locations, Point Loma Ocean Outfall Monitoring Program.

trawl fitted with a 1.3-cm cod-end mesh net. The net was towed for 10 minutes bottom time at a speed of about 2.0 knots along a predetermined heading.

The total catch from each trawl was brought onboard ship for sorting and inspection. All fishes and invertebrates captured were identified to species or to the lowest taxon possible. If an animal could not be identified in the field, it was returned to the laboratory for further identification. For fishes, the total number of individuals and total biomass (kg, wet weight) were recorded for each species. Additionally, each individual fish was inspected for physical anomalies or indicators of disease (e.g., tumors, fin erosion, discoloration) as well as the presence of external parasites, and then measured to the nearest centimeter size class (standard lengths). For invertebrates, the total number of individuals was recorded per species. Due to the small size of most organisms, invertebrate biomass was typically measured as a composite weight of all species combined; however, large or exceptionally abundant species were weighed separately.

Data Analyses

Populations of each fish and invertebrate species were summarized as percent abundance, frequency of occurrence, mean abundance per haul, and mean abundance per occurrence. In addition, species richness (number of taxa), total abundance, total biomass, and Shannon diversity index (H') were calculated for each station. For historical comparisons, the data were grouped as “nearfield” stations (SD10, SD12), “south farfield” stations (SD7, SD8), and “north farfield” stations (SD13, SD14). The two nearfield stations were those located closest to the outfall (i.e., within 1000 m of the north or south diffuser legs).

A long-term multivariate analysis of demersal fish communities in the region was performed using data collected from 1991 through 2009. However, in order to eliminate noise due to natural seasonal variation in populations, this analysis was limited to data for the July surveys only over these 19 years. PRIMER software was used to examine spatio-temporal patterns in the overall similarity of fish assemblages in the region (see Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking, and ordination by non-metric multidimensional scaling (MDS). The fish abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for classification. Because species composition was sparse at some stations, a “dummy” species with a value of one was added to all samples prior to computing similarities (see Clarke and Gorley 2006). SIMPER analysis was subsequently used to identify which species primarily account for observed differences between cluster groups, as well as to identify species typical of each group.

Results and Discussion

Fish Community

Twenty-six species of fish were collected in the area surrounding the PLOO in 2009 (Table 6.1,

Table 6.1
Demersal fish species collected in eight trawls in the PLOO region during 2009. PA = percent abundance; FO = frequency of occurrence; MAO = mean abundance per occurrence; MAH = mean abundance per haul.

Species	PA	FO	MAO	MAH	Species	PA	FO	MAO	MAH
Pacific sanddab	50	100	102	102	California tonguefish	1	50	3	1
California lizardfish	11	75	30	22	Yellowchin sculpin	1	25	6	1
Halfbanded rockfish	8	100	16	16	California scorpionfish	<1	13	8	1
Dover sole	6	100	13	13	Spotted cuskeel	<1	50	2	1
Longspine combfish	6	100	13	13	Roughback sculpin	<1	38	2	1
Shortspine combfish	5	100	10	10	Bigmouth sole	<1	25	3	1
English sole	3	88	7	6	Longfin sanddab	<1	25	1	<1
Pink seaperch	2	75	6	5	White croaker	<1	13	2	<1
Plainfin midshipman	2	100	4	4	Bluebanded ronquil	<1	13	1	<1
Slender sole	2	63	5	3	Flag rockfish	<1	13	1	<1
Stripetail rockfish	1	63	3	2	Smooth stargazer	<1	13	1	<1
Hornyhead turbot	1	63	3	2	Spotfin sculpin	<1	13	1	<1
Greenstriped rockfish	1	63	2	2	Wolf-eel	<1	13	1	<1

Appendix E.1). The total catch for the year was 1645 individuals, representing an average of about 206 fish per trawl. As in previous years, Pacific sanddabs were dominant, occurring in every haul and accounting for 50% of the total number of fishes collected. Halfbanded rockfish, Dover sole, longspine combfish, shortspine combfish, and plainfin midshipman were also collected in every haul, but in much lower numbers. Other species collected frequently (≥75% of the trawls) included California lizardfish, English sole, and pink seaperch. Pacific sanddabs averaged 102 fish per occurrence, while all other species averaged 30 or less with each contributing to no more than 11% of the total catch. The majority of species captured in the Point Loma region tended to be relatively small fish with an average length ≤20 cm (see Appendix E.1). Although larger species such as the California scorpionfish and wolf-eel were also captured during the year, these fish were relatively rare.

No more than 17 species of fish occurred in any one haul during 2009, and the corresponding diversity (H') values were all less than 2.2 (Table 6.2). Total abundance ranged from 108 to 377 fishes per haul; these differences tended to reflect variation in Pacific sanddab populations, which ranged between 27–167 fish per catch (Appendix E.2). Fish biomass ranged from 3.5 to 9.7 kg per haul, with higher values coincident with either greater numbers of fishes or the presence of large individual fish. For example, the highest biomass measured during the year was 9.7 kg at station SD10 in January, which was due to both a large haul of Pacific sanddabs weighing 4.3 kg and a large wolf-eel with an individual weight of 2.5 kg (see Appendix E.3).

Large fluctuations in populations of a few dominant species have been the primary factor contributing to the high variation in fish community structure off Point Loma since 1991 (Figure 6.2, 6.3). For example, species richness values for individual trawls performed within the PLOO region over this time period have ranged from 7 to 26 species, while total abundance per haul has varied from 44 to 2322 individuals/station/survey. The fluctuations in abundance have been greatest at stations SD10, SD12, SD13 and SD14 and generally reflect differences in populations of several dominant species. For example, overall abundance has been low since January 2007 due to significantly fewer numbers of Pacific sanddabs, yellowchin sculpin, longspine combfish, Dover sole, and halfbanded rockfish captured during each survey at most stations. Moreover, changes in dominant species over time have generally been similar among stations near the outfall and those at the northern sites. None of the observed changes in fish populations appear to be associated with wastewater discharge.

Table 6.2

Summary of demersal fish community parameters for PLOO stations sampled during 2009. Data are included for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight); ns = not sampled; SD = standard deviation.

Station	Winter	Summer
Species Richness		
SD7	ns	12
SD8	ns	17
SD10	15	13
SD12	12	14
SD13	ns	14
SD14	ns	14
Survey Mean	14	14
Survey SD	2	2
Abundance		
SD7	ns	163
SD8	ns	185
SD10	222	108
SD12	143	377
SD13	ns	151
SD14	ns	296
Survey Mean	183	213
Survey SD	56	102
Diversity		
SD7	ns	1.11
SD8	ns	1.64
SD10	1.53	1.40
SD12	2.19	1.81
SD13	ns	1.89
SD14	ns	1.68
Survey Mean	1.86	1.59
Survey SD	0.46	0.29
Biomass		
SD7	ns	4.3
SD8	ns	5.5
SD10	9.7	3.5
SD12	8.6	6.2
SD13	ns	4.4
SD14	ns	9.2
Survey Mean	9.1	5.5
Survey SD	0.8	2.0

Ordination and classification analyses of fish abundance data from 1991 through 2009 distinguished between eight main cluster groups or assemblages (cluster groups A–H; see Figure 6.4). These results indicate that the demersal fish community off Point Loma remains dominated by Pacific sanddabs, with differences in the relative abundance of this or other common species discriminating between the different cluster groups (see Table 6.3, Appendix E.4). During 2009, assemblages at all of the stations except SD10 were similar to those that occurred during 2006–2008 at all stations except SD7 (see description of group G below). There do not appear to be any spatial or temporal patterns that can be attributed to the outfall or the onset of wastewater discharge. Instead, most differences in local fish assemblages appear to be more closely related to large-scale oceanographic events (e.g., El Niño conditions in 1998) or the unique characteristics of a specific station. For example, fish assemblages at stations SD7 and SD8 located south of the outfall and not far from the LA-4 and LA-5 disposal sites, respectively, often grouped apart from the remaining trawls stations. The composition and main characteristics of each cluster group are described in the paragraphs that follow.

Cluster groups A–E comprised five unique assemblages, each represented by 1–3 station/survey entities (i.e., trawl catches), and accounting for <8% of the total number of trawls. Although most of these groups were dominated by Pacific sanddabs, they were unique compared to the other assemblages (i.e., cluster groups F–H) in terms of lower total abundance, fewer species, and/or relatively high numbers of less common fishes (e.g, midshipman, rockfish). Cluster group A represented the assemblage from station SD10 sampled in 1997, which was characterized by the fewest species and total number of fish per haul (i.e., 7 species, 44 fish), as well as the fewest Pacific sanddabs. Cluster group B represented the catch from stations SD7 and SD8 sampled in 2001, while group C was comprised of trawls from station SD8 in 1994, SD14 in 1998, and SD10 in 2009. These two assemblages were characterized by a few more species than group A (i.e., 11 species), and both groups also had low total abundances and relatively low average numbers of Pacific sanddabs. Cluster group D represented the assemblage from station SD12 sampled in 1998. This assemblage was unique because of the occurrence of a large population of plainfin midshipman, as well as a few less common

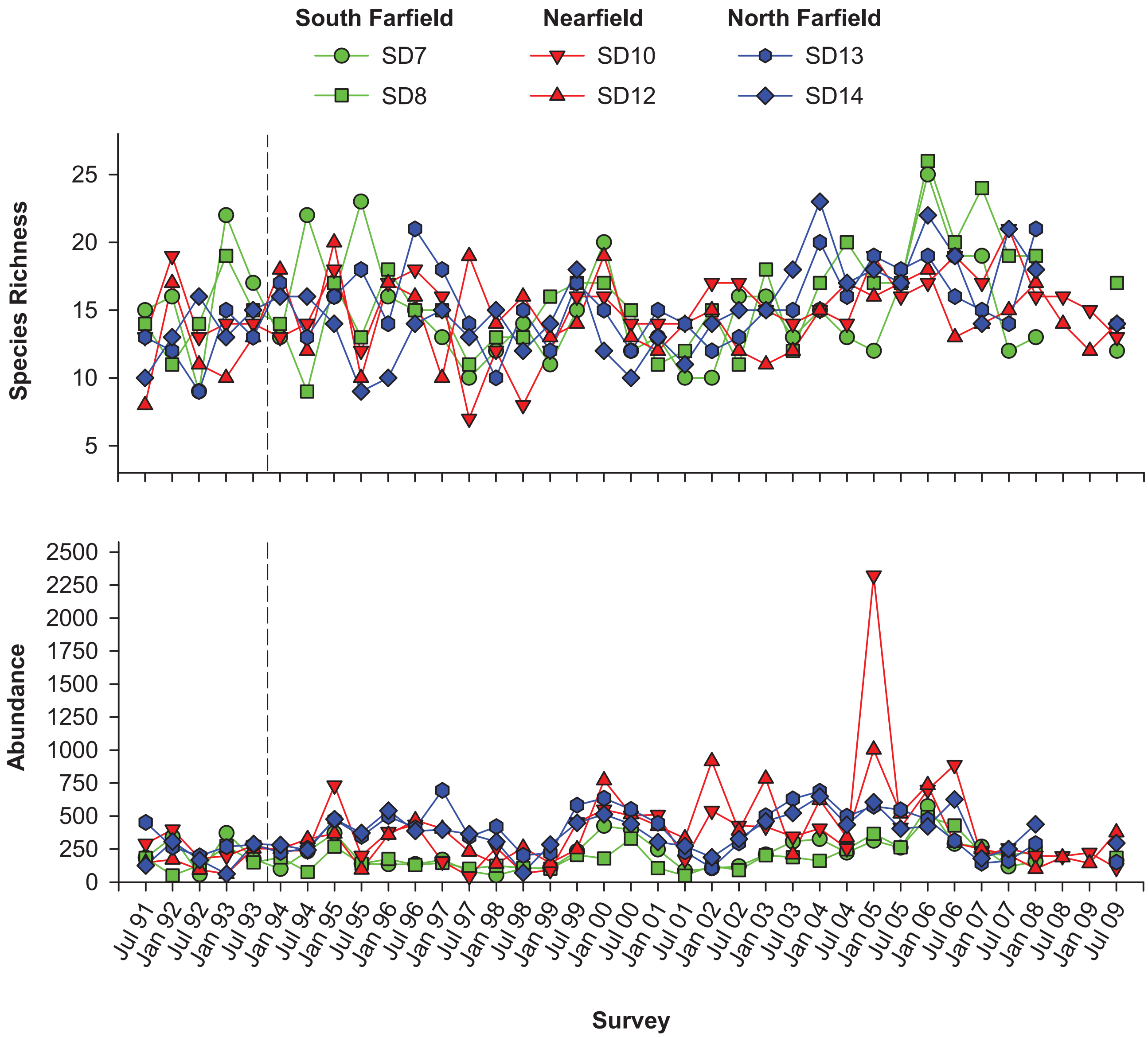

Figure 6.2
Species richness and abundance of demersal fish collected at each PLOO trawl station between 1991 and 2009. Data are total number of species and total number of individuals per haul, respectively. Dashed line represents initiation of wastewater discharge.

species (e.g., gulf sanddab). Cluster group E represented the assemblage from station SD12 sampled in 1997, which had the highest number of species over all groups, and was distinguished from other assemblages by relatively high numbers of halfbanded rockfish and squarespot rockfish.

Cluster group F represented the assemblage characteristic of 30 trawls. This included 18 of 24 trawls at stations SD7 and SD8 sampled between 1991–2002, trawls from all of the other stations (i.e., SD10–SD14) sampled during 1991–1992, and trawls from stations SD10 and SD12 in 1995, station SD10 in 1998, and station SD7 in 2007. Overall, this group was characterized by moderate numbers of fishes and slightly different species composition. The Pacific sanddab was the dominant species in this group with an average of about 97 fish/haul, while the Dover sole and longfin sanddab were the next two most characteristic species. The

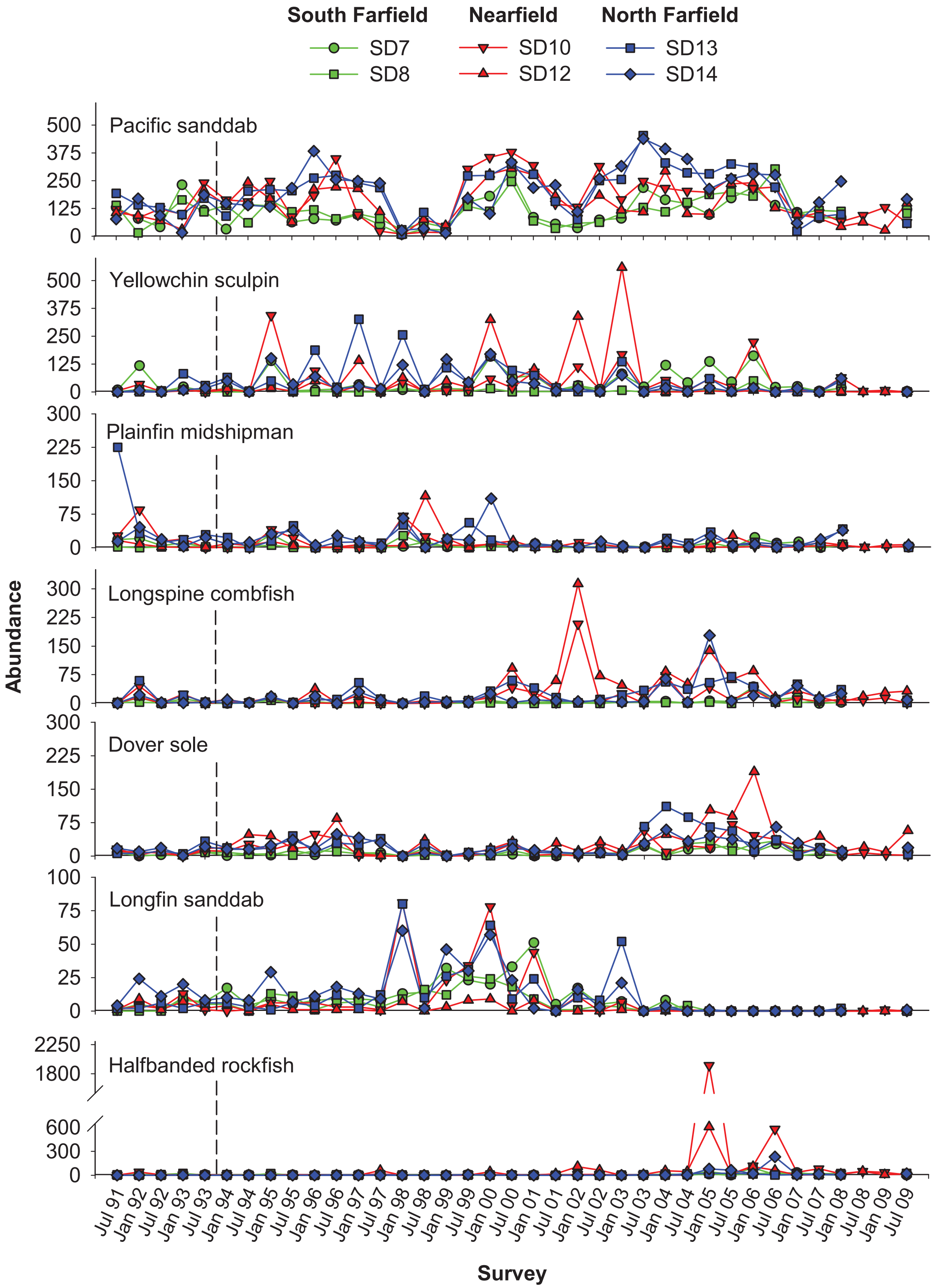

Figure 6.3
The seven most abundant fish species collected in the PLOO region from 1991 through 2009. Data are total number of individuals per haul. Dashed line represents initiation of wastewater discharge.

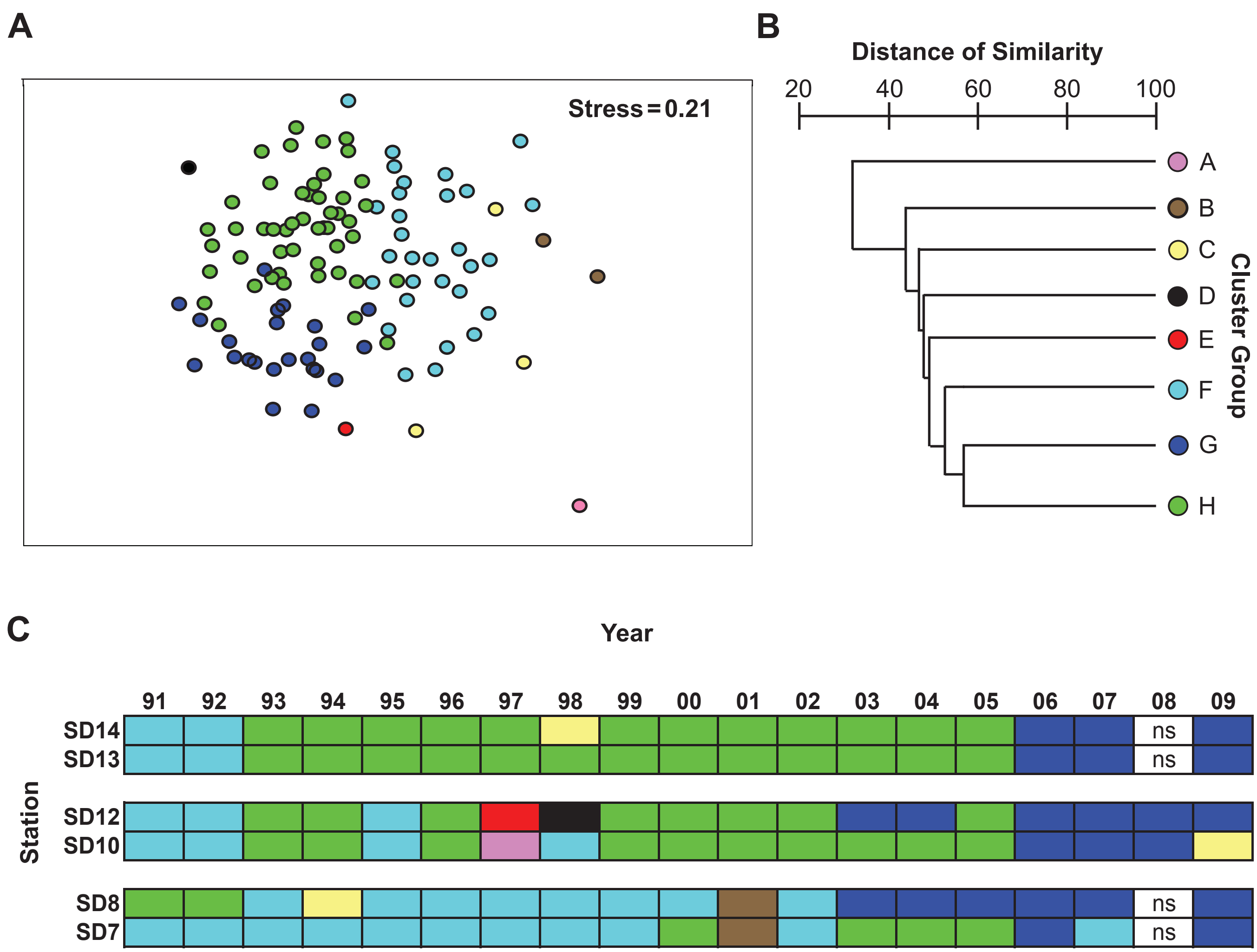

Figure 6.4

Results of classification analysis of demersal fish assemblages collected at PLOO stations SD7–SD14 between 1991 and 2009 (July surveys only). Data are presented as (A) MDS ordination, (B) a dendrogram of major cluster groups, and (C) a matrix showing distribution of cluster groups over time; ns = not sampled.

relative abundances of the above three species plus halfbanded rockfish, stripetail rockfish, plainfin midshipman, and squarespot rockfish distinguished this cluster group from all others.

Cluster group G comprised the assemblages from all but one station sampled during 2009, as well as the only two stations sampled during the July 2008 survey (i.e., SD10, SD12), all stations except SD7 in 2006 and 2007, SD12 during 2003–2004, and SD8 between 2003 and 2005. This group was characterized by relatively high numbers of Pacific sanddabs (~142 fish/haul), halfbanded rockfish (~55 fish/haul), and Dover sole (~26 fish/haul). The higher abundances of these three species helped distinguish this group from all others.

Cluster group H may represent "normal" or "background" conditions in the PLOO region, representing assemblages from 45% of all trawls included in the analysis. Most of these assemblages were sampled at stations around or north of the PLOO between 1993 and 2005 (i.e., stations SD10–SD14). The main exceptions occurred during and after the 1998 El Niño (i.e., 1997–1999). This group was characterized by the highest average numbers of Pacific sanddabs (~239 fish/haul) and the second highest average numbers of Dover sole (~29 fish/haul). The next three most abundant species in this group

Table 6.3

Description of cluster groups A–H defined in Figure 6.4. Data include number of hauls, mean species richness, mean total abundance, and mean abundance of the five most abundant species for each station group. Bold values indicate species that were considered "characteristic" of that group according to SIMPER analyses (i.e., similarity/standard deviation ≥ 2.0).

	Cluster Groups							
	A	B	C	D	E	F	G	H
Number of Hauls	1	2	3	1	1	30	23	49
Mean Species Richness	7	11	11	16	19	13	16	15
Mean Abundance	44	68	85	261	231	162	292	363
Species	**Mean Abundance**							
Pacific sanddab	23.0	45.5	**52.7**	75.0	110.0	**97.4**	**142.4**	**239.0**
Dover sole	—	1.0	**4.3**	36.0	1.0	**10.0**	**25.5**	**29.4**
Yellowchin sculpin	—	5.0	—	—	—	3.5	1.5	16.9
Longspine combfish	—	2.5	1.7	7.0	2.0	0.7	11.1	14.3
Stripetail rockfish	—	—	5.0	1.0	5.0	8.3	2.4	13.2
Plainfin midshipman	—	—	**2.0**	116.0	4.0	14.6	4.1	8.9
Halfbanded rockfish	16.0	—	1.3	—	60.0	1.8	**55.8**	6.7
Longfin sanddab	1.0	3.0	0.7	—	—	**6.8**	0.2	5.9
Pink seaperch	1.0	0.5	1.0	4.0	1.0	0.9	4.3	4.6
Shortspine combfish	—	—	0.3	—	3.0	2.1	11.4	2.1
Greenblotched rockfish	—	0.5	1.0	—	8.0	0.7	0.4	1.2
Bigmouth sole	—	2.5	—	—	1.0	0.9	0.7	0.8
California tonguefish	—	2.5	—	—	1.0	3.3	1.8	0.8
Gulf sanddab	1.0	—	0.7	5.0	—	0.2	—	0.7
Greenspotted rockfish	1.0	—	—	—	1.0	0.4	—	0.4
California lizardfish	—	1.0	8.7	—	—	0.5	7.5	0.4
Roughback sculpin	—	1.5	0.3	2.0	—	0.3	0.6	0.3
Spotfin sculpin	1.0	—	1.0	—	—	2.1	1.8	0.2
Squarespot rockfish	—	0.5	—	—	23.0	0.1	0.1	—
Vermilion rockfish	—	—	—	—	6.0	—	—	—

were yellowchin sculpin (17 fish/haul), longspine combfish (~14 fish/haul), and stripetail rockfish (13 fish/haul). The higher numbers of these five species, plus moderate numbers of longfin sanddab, plainfin midshipman and halfbanded rockfish, distinguished group H from the other assemblages.

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the PLOO region during 2009. There were no incidences of fin rot, discoloration, skin lesions, tumors or any other indicators of disease among fishes collected during the year. Evidence of parasitism was also very low for trawl-caught fishes off Point Loma. Although the copepod *Phrixocephalus cincinnatus* infected ~2% of the Pacific sanddabs collected during the year, this eye parasite was found on fish collected during each survey, and at least once from each station. In addition, three *Elthusa vulgaris* (Isopoda, Cymothoidae) were identified as part of the trawl catch throughout the year (see Appendix E.5). Since cymothoids often become detached from their hosts during retrieval and sorting of the trawl catch, it is unknown which fishes were actually parasitized by these isopods. However, *E. vulgaris* is known to be especially common on sanddabs and California lizardfish in southern California waters, where it may reach infestation rates of 3% and 80%, respectively (see Brusca 1978, 1981).

Table 6.4

Species of megabenthic invertebrates collected in eight trawls in the PLOO region during 2009. PA = percent abundance; FO = frequency of occurrence; MAO = mean abundance per occurrence; MAH = mean abundance per haul.

Species	PA	FO	MAO	MAH	Species	PA	FO	MAO	MAH
Lytechinus pictus	92	100	1229	1229	*Amphichondrius granulatus*	<1	13	<1	1
Strongylocentrotus fragilis	3	25	46	184	*Armina californica*	<1	13	<1	1
Acanthoptilum sp	3	100	44	44	*Hololepida magna*	<1	13	<1	1
Ophiura luetkenii	1	88	8	9	*Luidia asthenosoma*	<1	13	<1	1
Luidia foliolata	<1	50	3	6	*Octopus rubescens*	<1	13	<1	1
Parastichopus californicus	<1	88	3	3	*Paguristes turgidus*	<1	13	<1	1
Sicyonia ingentis	<1	38	2	4	*Pteropurpura* sp	<1	13	<1	1
Astropecten verrilli	<1	50	1	2	*Pyromaia tuberculata*	<1	13	<1	1
Philine alba	<1	38	1	2	*Spatangus californicus*	<1	13	<1	1
Rossia pacifica	<1	25	<1	2	*Suberites* sp	<1	13	<1	1
Elthusa vulgaris	<1	13	<1	3	*Telesto californica*	<1	13	<1	1
Megasurcula carpenteriana	<1	25	<1	1	*Thesea* sp B	<1	13	<1	1
Metridium farcimen	<1	13	<1	2					

Invertebrate Community

A total of 10,702 megabenthic invertebrates (~1338 per trawl) representing 25 taxa were collected during 2009 (Table 6.4, Appendix E.5). As in previous years, the sea urchin *Lytechinus pictus* was the most abundant and most frequently captured species, occurring in all trawls and accounting for 92% of the total invertebrate abundance. The sea pen *Acanthoptilum* sp was also collected in every haul, but in much lower numbers. Other common species that occurred in 50% or more of the hauls included the brittle star *Ophiura luetkenii,* the sea cucumber *Parastichopus californicus,* and the sea stars *Astropecten verrilli* and *Luidia foliolata*.

Megabenthic invertebrate community structure varied among stations and between surveys during the year (Table 6.5). Species richness ranged from 5 to 11 species per haul, diversity (H') values ranged from 0.04 to 1.09 per haul, and total abundance ranged from 234 to 3844 individuals per haul. Patterns in total invertebrate abundance tended to mirror variation in *L. pictus* populations (Appendix E.6). For example, stations SD8, SD10, and SD12 had much higher invertebrate abundances than the other three stations due to relatively large catches of *L. pictus* (i.e., ≥1300/haul). The low diversity values (≤1.09) for the region were due to the numerical dominance of this sea urchin. Dominance of *L. pictus* is typical for these types of habitats throughout the SCB (e.g., Allen et al. 1998).

Invertebrate species richness and abundances have varied over time (Figure 6.5). For example, species richness has ranged from 3 to 29 species per year since 1991, although patterns of change have been similar among stations. In contrast, changes in total abundance have differed greatly among the trawl stations. The average annual invertebrate catches have been consistently low at stations SD13 and SD14, while the remaining stations have demonstrated large fluctuations in abundance. These fluctuations typically reflect changes in *L. pictus* populations, as well as populations of *Acanthoptilum* sp, the sea urchin *Strongylocentrotus fragilis*, the shrimp *Sicyonia ingentis*, and the sea star *Astropecten verrilli* (Figure 6.6). Additionally, abundances of *L. pictus* and *A. verrilli* are typically much lower at the two northern sites, which likely reflect differences in sediment composition (e.g., fine sands vs. mixed coarse/fine sediments, see Chapter 4). None of the observed variability in the trawl-caught invertebrate community appeared related to the discharge of wastewater from the PLOO.

Table 6.5

Summary of megabenthic invertebrate community parameters for PLOO stations sampled during 2009. Data are included for species richness (number of species), abundance (number of individuals), and diversity (H'); ns = not sampled; SD = standard deviation.

Station	Winter	Summer
Species Richness		
SD7	ns	7
SD8	ns	11
SD10	6	9
SD12	5	9
SD13	ns	8
SD14	ns	9
Survey Mean	6	9
Survey SD	1	1
Abundance		
SD7	ns	754
SD8	ns	1386
SD10	2110	1536
SD12	3844	251
SD13	ns	234
SD14	ns	587
Survey Mean	2977	791
Survey SD	1226	557
Diversity		
SD7	ns	0.15
SD8	ns	0.10
SD10	0.04	0.09
SD12	0.13	0.73
SD13	ns	1.09
SD14	ns	1.08
Survey Mean	0.08	0.54
Survey SD	0.06	0.48

Summary and Conclusions

Pacific sanddabs continued to dominate fish assemblages surrounding the Point Loma Ocean Outfall during 2009 as they have for many years. This species occurred at all stations and accounted for 50% of the total fish catch. Other characteristic, but less abundant species of fish included halfbanded rockfish, Dover sole, longspine combfish, shortspine combfish, plainfin midshipman, California lizardfish, English sole, and pink seaperch. Most of these common fishes were relatively small, averaging less than 20 cm in length. Although the composition and structure of the fish assemblages varied among stations, most differences were due to fluctuations in Pacific sanddab populations.

Assemblages of megabenthic invertebrates in the region were similarly dominated by a single species, the sea urchin *Lytechinus pictus.* Variations in overall community structure of the trawl-caught invertebrates generally reflect changes in the abundance of this urchin, as well as several other dominant species. These other species include the sea pen *Acanthoptilum* sp, the sea stars *Astropecten verrilli* and *Luidia foliolata*, the sea cucumber *Parastichopus californicus*, and the brittle star *Ophiura luetkenii*.

Overall, results of the 2009 trawl surveys provide no evidence that wastewater discharged through the PLOO has affected either demersal fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of trawl-caught fishes and invertebrates were similar at stations located near the outfall and farther away. These results are supported by the findings of another recent assessment of these communities off San Diego (City of San Diego 2007). Significant changes in these communities appear most likely to be due to natural factors such as changes in ocean water temperatures associated with large-scale oceanographic events or to the mobile nature of many of resident species. Finally, the absence of disease or other physical abnormalities in local fishes suggests that their populations continue to be healthy off Point Loma.

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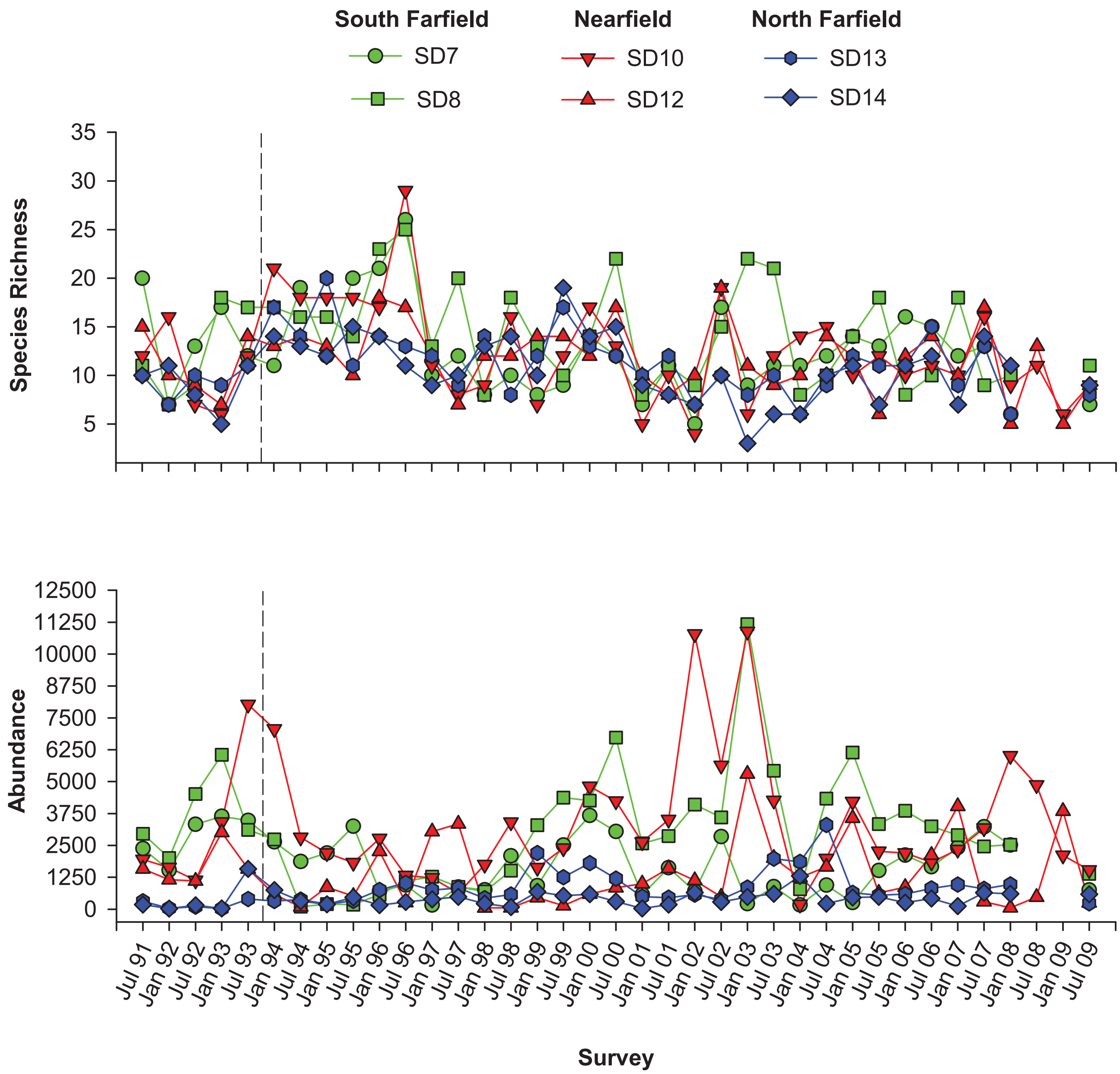

Figure 6.5
Species richness and abundance of megabenthic invertebrates collected at each PLOO trawl station between 1991 and 2009. Data are total number of species and total number of individuals per haul, respectively. Dashed line represents initiation of wastewater discharge.

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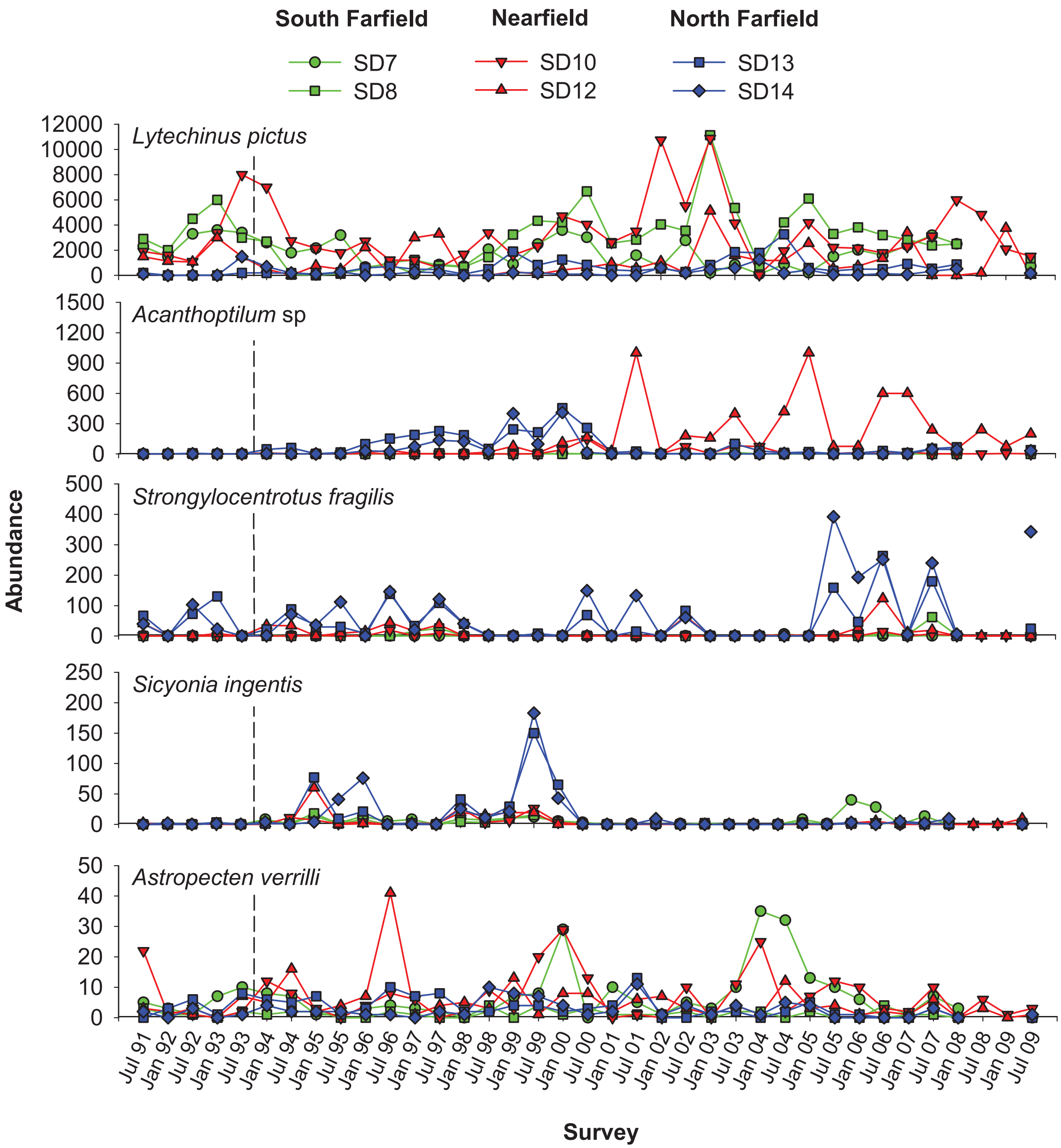

Figure 6.6

The five most abundant megabenthic species collected in the PLOO region from 1991 through 2009. Data are total number of individuals per haul. Dashed line represents initiation of wastewater discharge.

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